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MICROSTRUCTURE AND DRY SLIDING WEAR BEHAVIOUR OF LM6 ALLOY SOLIDIFIED UNDER THE INFLUENCE OF LOW FREQUENCY MOLD VIBRATION

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ABSTRACT

In the present work, solidifying melt of LM6 was subjected to low frequency vibration and the effects on microstructure and dry sliding wear were studied. Volume loss due to wear under different service conditions of varying normal load, sliding speed and sliding distance was considered for investigation. The other beneficial effects of mold vibration include grain refinement.

KEYWORDS: Mechanical Mold Vibration & Dry Sliding Wear Test

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Original Article

INTRODUCTION

In recent years, extensive study on several parameters which can influence the solidification mechanism of metal/alloys has been carried out. Rate of cooling, gravitation and magnetic field and subjecting the mold to vibration (both sonic and ultrasonic) have been discussed as possible means of altering the grain structure of Aluminum- Silicon (Al-Si) alloys. Subjecting the solidifying melt to forced convection or vibration has generated interest among researchers due to several advantages like grain refinement and improvement of mechanical properties. Grain structure of casting changes from columnar dendritic to equiaxed dendrites or globular. Refinement of grain structure influences the properties of the castings to a large extent. It has been observed that in order to get pronounced grain refinement, the melt should be maintained under the influence of vibration energy for reasonably long time. This can be done by choosing alloys with long freezing range or preheating the mold.

Al-Si alloys, are extensively used in components subjected to extensive wear like automotive and aircraft components. They can be easily cast into desired shape and size, have superior strength to weight ratio and offer excellent corrosion resistance. The tribological behaviour of Al-Si alloys is related to the distribution of Silicon in the Aluminum matrix.

Al-Si alloy solidified under the influence of vibration resulted in refinement of grain [1], reduction in piping [2], dendritic fragmentation and transformation of eutectic silicon from flake-like to fibrous structure [3] and modification of silicon needle [4]. Therefore, it can be concluded that vibrating the mold during solidification bring changes in microstructure and properties. Techniques for producing vibration depend on the source of producing vibration, from electromagnetic [5] to ultrasonic vibration [6]. Many researchers have mechanically vibrated the mold

[7, 8, and 9].

In the present work, LM6 alloy, the composition of which is similar to eutectic Al-Si alloy is solidified in mold of cast iron and graphite which are vibrated mechanically during pouring and solidification stages. The pouring temperature has also been varied to further increase the scope of study. The microstructural properties along with wear behavior of the as cast alloy is studied.

EXPERIMENTAL

The casting methodology is similar to the work published by the authors earlier [10]. The parameters of vibration are 25 Hz frequency and 0.05 mm amplitude. Electrical resistance furnace which can be maintained at temperature of 1000°C was used to melt LM6 alloy. After superheating the alloy to a temperature of 850°C, the melt treated with proper degassing agent was poured in the vibrating mold maintained at 200°C. Temperature of the charge was measured just before pouring and was ascertained to be 700°C and 800°C. It is imperative that the mold vibration be maintained during pouring and until the melt solidified.

The cast ingots were split to study the microstructure and to conduct dry sliding wear test. The microstructure examinations, as per ASTM-E407 standard was carried out on one half of the cast ingot. Nikon make optical metallurgical microscope was used to measure average grain size number and dendrite arm spacing.

Dry sliding wear specimens were prepared from locations of the cast ingots as shown in figure 1. The wear test specimens of 5 mm diameter and 20 mm in length from each casting were prepared. The standard for carrying dry sliding wear test was ASTM: G 99-05. Ducom make wear testing instrument coupled to a data acquisition software was utilized for conducting the test. The specimen was so placed such that its end face was sliding against the rotating face of the disc. The specimen were subjected to wear tests in an atmosphere resembling the in-service conditions by varying the normal load (4.9 N, 9.8 N,14.7 N), sliding speeds (5.494 m/s, 7.326 m/s, 9.158 m/s) and sliding distances (9891 m, 19780.2 m, 32968.8 m) . The face of the rotating disc and the end face of the test specimen were adequately cleaned by acetone after which they were dried properly before the tests were initiated. Wear was measured as volume loss in mm^3.

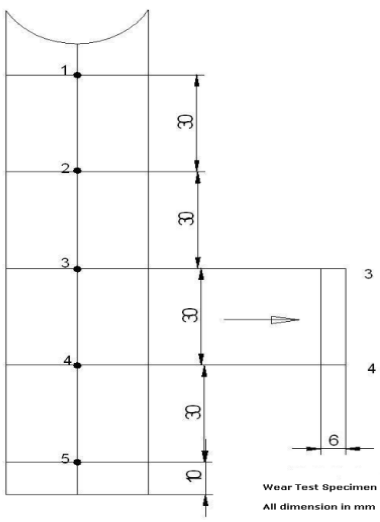

Figure 1: Location of Wear Specimen Selected from the as Cast Ingot.

RESULTS AND DISCUSSIONS

Microstructure Study

From microstructures in figure 2 and 3, it can be observed that casting in stationary mold encourages dendritic growth whereas if the mold is subjected to vibration, the dendritic growth has been curtailed. At pouring temperature of 700°C, the microstructure of the specimen contains fragmented dendrites, whereas in the microstructure of the specimen cast at 800°C pouring temperature, dendritic growth is dominant. LM6 alloy behaves as hypoeutectic alloy and solidification starts at around 600°**C.** hence pouring temperature of 700°C does not allow sufficient time for the dendrites to grow. Higher pouring temperature combined with mold vibration provides sufficient time for vibration to act on the solidifying melt causing fragmentation. Cast iron molds encourages dendritic growth whereas graphite mold does not, which may be due to the different thermal characteristics of the two materials.

Comparing the microstructure of cast specimen in static mold with mold subjected to vibration as seen in figure 2 and figure 3, it is observed that vibrating the mold mechanically causes a stirring action in the solidifying melt during solidification resulting in fragmentation. These fragmented solid crystals act as nuclei for the remaining liquid melt thereby encouraging grain refinement. Therefore it can deduced that subjecting the molten melt to disturbances during solidification resulted in grain refinement by fragmentation of the initial dendrites formed. These fragmented dendrite act as nuclei for the growth of equiaxed grains leading to a finer microstructure.

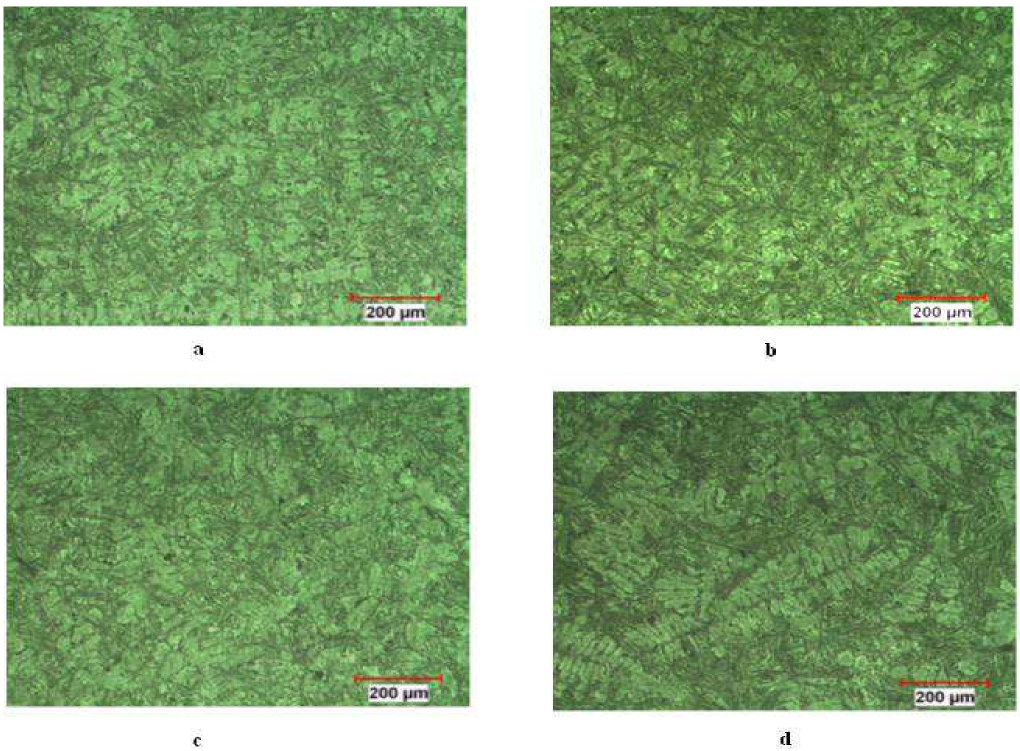

Figure 2: Microstructure of Cast Specimen in Static Mold at 100x Magnification Poured in Cast Iron Mold at (a) 700°C and (b) 800°C and Graphite Mold Poured at (c) 700°C and (d) 800°C.

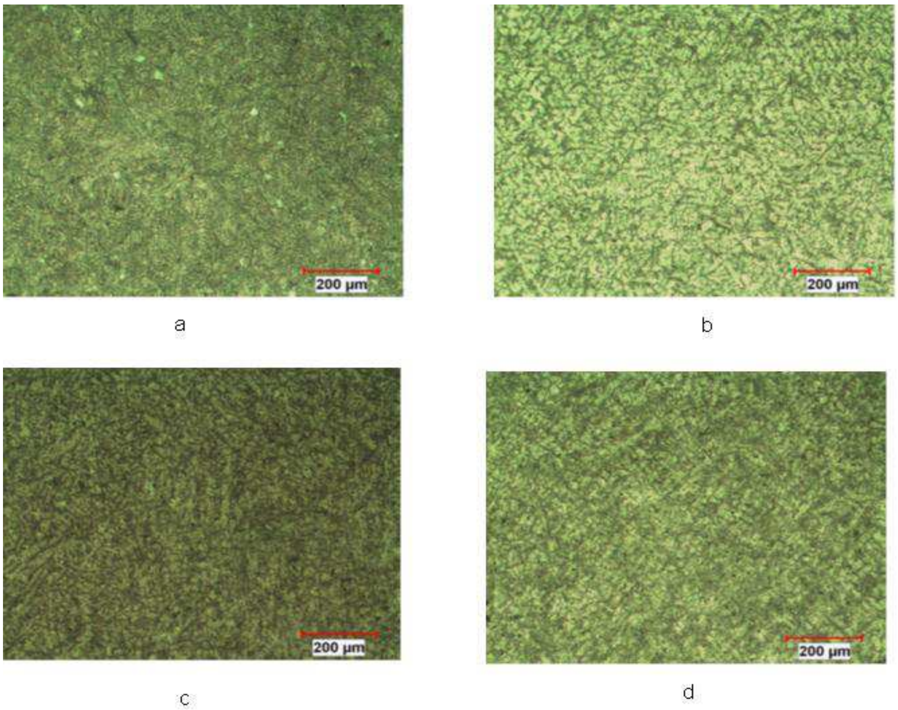

Figure 3: Microstructure of cast Specimen in Vibrated Mold at 100x Magnification Poured in Cast Iron Mold at (a) 700°C and (b) 800°C and Graphite Mold Poured at (c) 700°C and (d) 800°C.

Further, vibrating the mold results in movement of the metal adjacent to the mold walls, resulting in improved heat transfer. Under normal conditions, there will be hardly any contact between molten metal and mold wall because of the presence of oxide film. Inducing vibration has a tendency to break down the thin oxide film, thereby improving the contact between the melt and mold wall, thereby improving the heat transfer, preventing dendritic growth.

Average Grain Size Number and Dendritic Arm Spacing

It is observed from figure 4, that the average grain size number for specimen label 'abc', is highest indicating maximum grain refinement. Further it is observed from figure 5, that the dendritic arm spacing of specimen label 'abc' is least indicating fragmentation. Mold vibration during solidification causes reduction in dendritic arm spacing.

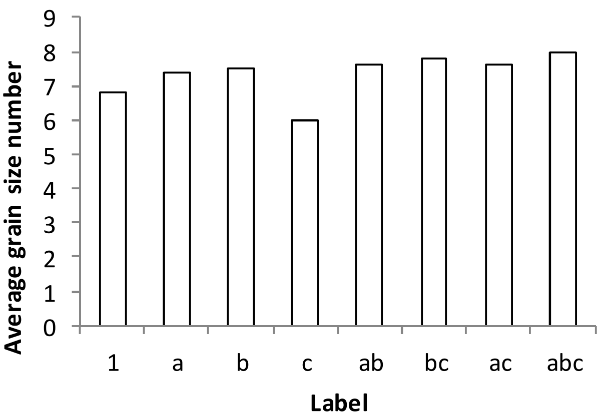

Figure 4: Average Grain Size Number v/s Label as Designated in Design Matrix Table 2.

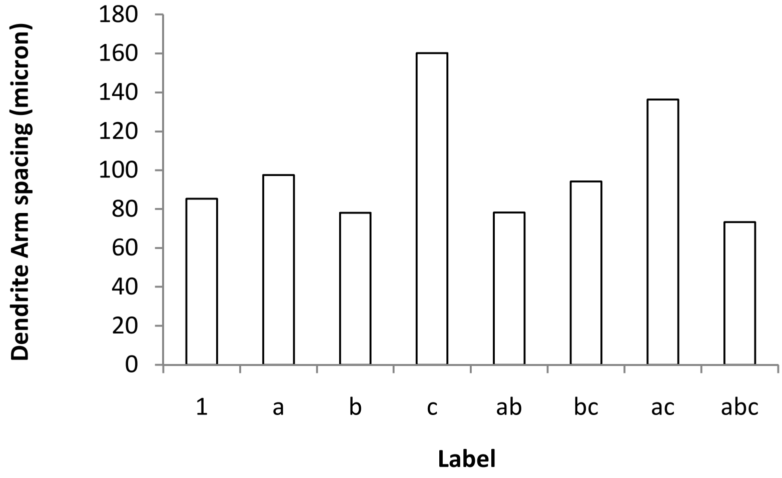

Figure 5: Average Dendrite Arm Spacing (Micron) v/s Label as Designated in Design Matrix Table 2.

Wear Studies

From the graph in figure 6, it is observed that the volume loss increases with the increase in normal load. A similar trend is observed from the graph in figure 7 and 8, where volume loss increases with the increase in sliding speed and sliding distance. It is observed that the specimen labelled 'abc' that is the specimen cast in vibrated mold has least wear volume as compared to the cast specimen in static mold.

The microstructure of specimens cast in stationary mold is made up of silicon with sharp ends, thereby raising the internal stress. This leads to the alloy becoming brittle and higher volume loss, whereas the microstructure of cast specimen in vibrated mold consists of fragmented or rounded silicon particle resulting in lower volume loss. It was also observed that silicon particles are more uniformly dispersed. The changed silicon morphology results in improved binding. This reduces the tendency to crack and lower volume loss.

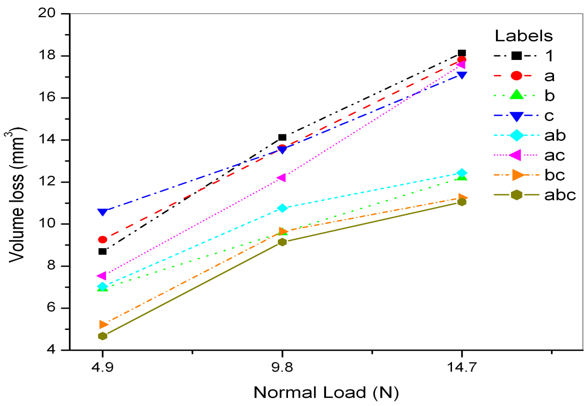

Figure 6: Volume Loss vs. Normal Load at Constant Sliding Speed of 5.495 m/s and Sliding Distance of 9891m.

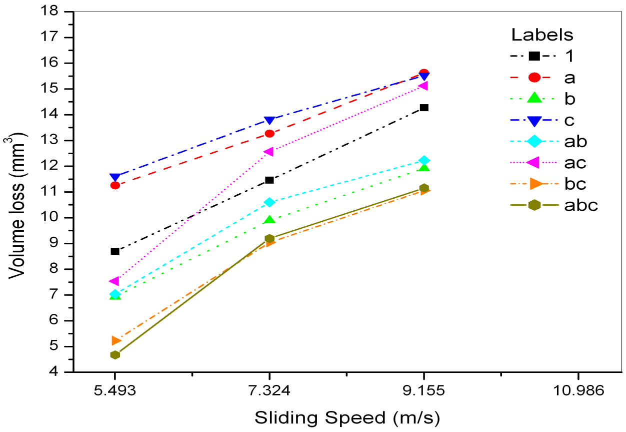

Figure 7: Volume Loss vs. Sliding Speed at Constant Normal Load of 4.9 N and Sliding Distance of 9891m.

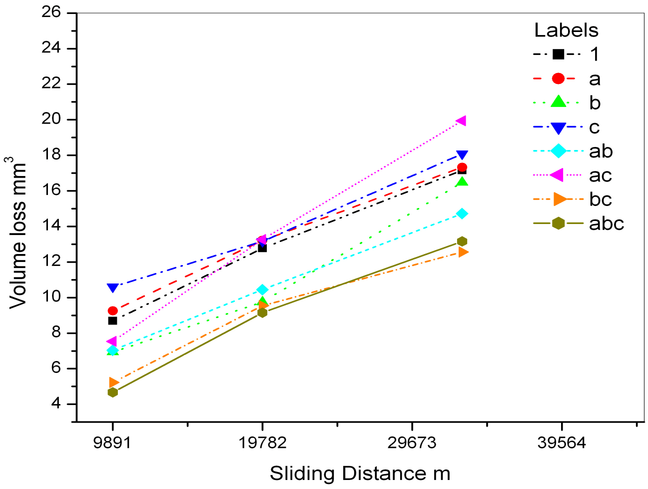

Figure 8: Volume Loss vs. Sliding Distance at Constant Normal Load of 4.9 N and Sliding Speed of 5.495 m/s.

Study of Worn Surfaces

Figure 9 shows the SEM images of the worn surfaces of specimen cast in stationary mold. The worn surface contains continuous parallel grooves indicating severe wear. Some large dimples can also be observed on the worn surfaces of the alloy, which indicates that silicon phases were fractured and broken off during wear.

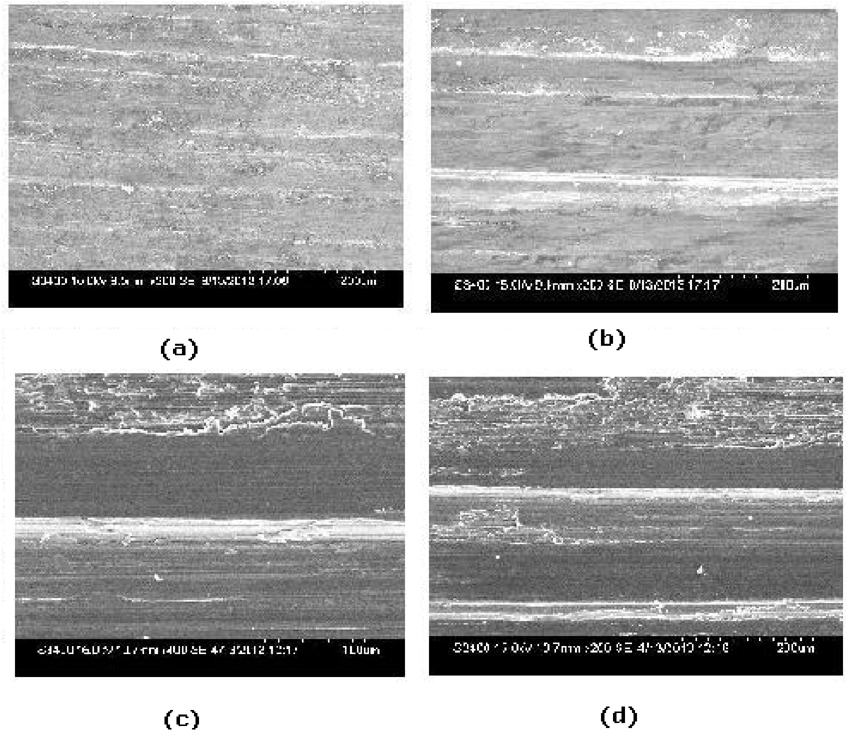

Figure 9: SEM of Worn Surfaces of Cast Specimen in Static Cast Iron Mold with Pouring Temperature of (a) 700°C and (c) 800 °C and Static Graphite Mold with Pouring Temperature of (b) 700 °C and (d) 800 °C.

Figure 10 shows the SEM images of worn surfaces of specimen cast in vibrated mold. The grooves depicted on the worn surface are shallow and uniform. This indicates that grain refinement and evenly distributed silicon in the matrix. This fine dispersion provides strength to the matrix leading to low wear.

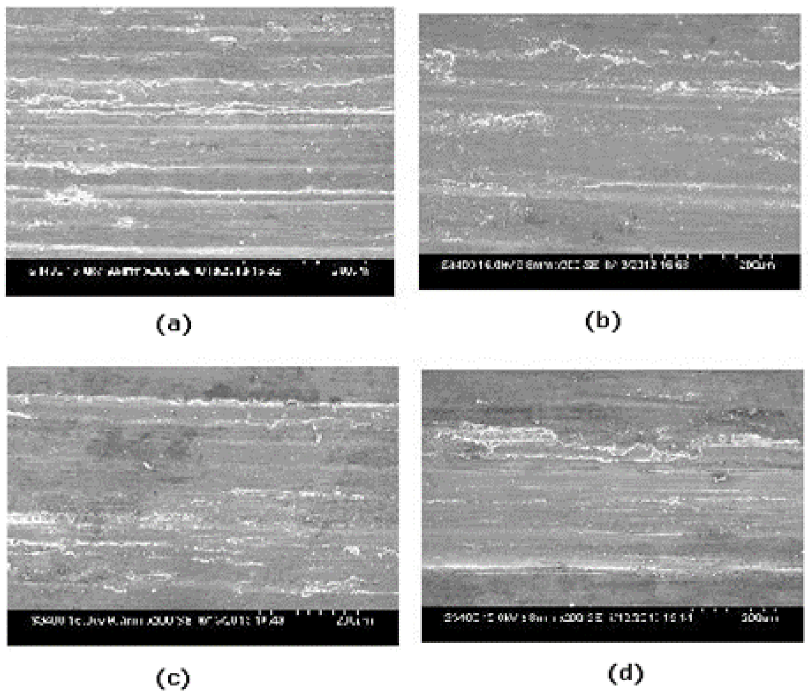

Figure 10: SEM of Worn Surfaces of Cast Specimen in Vibrated Cast Iron Mold with Pouring Temperature of (a) 700°C and (c) 800 °C and Static Graphite Mold with Pouring Temperature of (b) 700 °C and (d) 800 °C.

CONCLUSIONS

The present technique followed by industries involves use of master alloys of Al-Ti or Al-Ti-B to carry out grain refinement and modifiers like Sodium. However, the use of these reagents has limitations like fading effect and is not environment friendly. Hence, the technique studied in this paper is hoped to be beneficial to the industries producing Al-Si alloys. This technique may however have to be limited to smaller components because casting large sized components may be limited by the size of vibrators available in the market.

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